

Comments on “Impact of host climate model on contrail cirrus effective radiative forcing estimates” by Zhang et al. (2024)

General comments

In this study by Zhang et al., the authors analyse the impact of the choice of host climate model on the simulation of contrails, their feedbacks to natural clouds and their ERF. They achieve this by running the same contrail parameterisation in two different climate models, the UK Met Office Unified Model (UM) and the NCAR Community Atmosphere Model (CAM). A main difference between the two models which is highly relevant for contrail modelling consists in the complexity of their microphysics schemes, where the UM runs a single-ice-category one-moment cloud scheme and CAM features a two-moment scheme. Overall, the authors find large dependencies of the simulated contrails and their feedbacks on the chosen host climate model with sometimes even opposite signs. In order to evaluate the response of the ERF to the choice of climate model, the simulated optical depth of young contrails in the UM is scaled up linearly to be comparable to the one simulated by CAM. This analysis also reveals a large dependency on both, the chosen host climate model and the contrail optical depth. It is concluded that the uncertainties in modelling the contrail ERF are still large.

To my knowledge, this study is the first to investigate the impact of the host climate model on contrail ERF estimates, which is an important step towards understanding and narrowing down the large uncertainty estimated by Lee et al. (2021). This fits into the scope of ACP and is of urgent scientific interest, in particular in view of plans and ongoing attempts to avoid persistent contrails. Thus, the manuscript is suitable for publication in ACP.

However, some questions, which should be addressed in the manuscript, came to my mind, while reading. Also, I have a number of comments and suggestions for improving the manuscript further and recommend that the manuscript should be revised accordingly, before it can be published.

Specific comments

- Line 28f: Unclear what is meant with “When accounting for the difference in cloud microphysics complexity”. Suggestion: “When compensating the resulting unrealistically low contrail optical thickness in the UM”
- Line 31: The “factor of ~2” better matches the values for 2006. I suggest to either give the 2006 values in the sentence before or omit this parenthesis.
- Introduction: The authors write a lot about uncertainties in contrail cirrus RF and ERF. However, I missed a sentence on recent research suggesting a low efficacy of contrail cirrus ERF, potentially resulting in a low temperature response despite the high ERF, due to compensating slow feedbacks (e.g. Bickel 2023).
- Line 51f: This sentence seems a little out of context to me. If the intention is to state that also engines that do not emit soot can produce contrails, I suggest: “At present, the water vapour primarily condenses on particles emitted by today's kerosene combusting engines. However, these particle emissions are not necessary [...]”
- Introduction: I missed the usual paragraph on the structure of the paper.
- Equations 4 & 5: If I understand this correctly, specific quantities and mass mixing ratios are mixed here. The error is certainly negligible. If this is already mentioned in Chen et al. (2012), it is probably not necessary to repeat it here. However, please be aware of this imprecision.

- Line 195: Why “100 m x 100 m”? I would assume “contrails aged for 20–30 min” to be larger in cross section. Are the choices of particle radius and contrail cross section consistent with the model time step?
- Line 204ff: What were the reasons for the different treatment of perturbations, run time and nudging between the two models? Also, I suppose nudging the temperature, but not the humidity might have strong impacts on relative humidity. Please discuss.
- Line 246: I do not see a clear signal for East Asia in JJA, especially since it is claimed in section 3.2 that East Asia may compensate the lower ice supersaturation frequency in Europe and the USA in the UM in JJA.
- Figure 2: I wonder why the difference plots show dense air traffic over the North Atlantic, while the single-model plots do not. Is this an interpolation artefact?
- Line 267: I cannot reproduce the 0.00018% for CAM from figure 3e. Is this a non-normalised value?
- Line 269ff: Was this normalisation performed before or after adding up the model levels under the random overlap assumption? In the latter case, I would (in theory) expect the reduction to be too strong.
- Line 271f: This sounds quite certain that this is the only reason. Have you checked, whether there are also differences in the frequency of contrail generation in general (Schmidt-Appleman criterion) that could also contribute to more persistent contrails?
- Lines 301ff: I do not understand the second half of this paragraph. Before, it is claimed that the young contrail fraction depends on the total number of vertical levels rather than the resolution in the UTLS. But here, young contrail fractions from two simulations with similar vertical resolution in the UTLS, but clearly different numbers of vertical levels are compared and it is proposed that the differences result from differences in the model physics rather than the different number of vertical levels.
- Line 362f: Where do the “simulated contrail ice mass” and the “contrail cirrus optical depth” come from? As far as I understood, the model is unaware of what is contrail and what is natural cirrus. Is this scaling factor only calculated and applied for “young contrails”? If this is the case, I could imagine that this contributes to the lower ERF in the UM, since the contrails would only have the enhanced optical thickness during the first model timestep of their lifecycle.
- Line 389f: Here, the ERF from the scaled UM simulations is compared with the change in cloud fraction from the unscaled simulations. I wonder, whether the cloud fraction and also the actual ice water path (not the one inside the radiation scheme) are impacted by the change in the radiation scheme.
- Line 391f: Could you comment on this apparent inconsistency? Could it be that CAM does not consider the contrail ice crystals as a cloud anymore, when they have sedimented, such that they still inhibit natural cloud formation but do not appear in the cloud fraction anymore?
- Future work: I would also conclude that more studies of this kind with other climate models and other contrail parameterisations are needed, in order to give a reliable estimate of the model uncertainty and to narrow down the uncertainty together with better observational constraints.

Technical corrections

As I am not a native speaker, all language corrections are rather suggestions.

- Line 30, table 2 and also later: I suggest leaving a space between “mW” and “m⁻²”.
- Line 38: If the authors wish to introduce the abbreviation “CO₂”, this should be done on its first occurrence, not in line 44.

- Line 39f: "According to International [...] monitor, [...] has reached pre-pandemic [...] level" -> "According to the International [...] monitor, [...] has reached the pre-pandemic [...] level"
- Line 47: "(spreading [...])" -> "(i.e. spreading [...])"
- Line 48ff: The way the sentence is written, it appeared to me that the "cool ambient air" was "under liquid water saturation conditions". Suggestion: "Contrails are line-shaped high clouds that form whenever liquid water saturation is exceeded during the mixing between [...]"
- Line 56ff and also later: Not sure, but I think "Earth" comes without an article. Please check.
- Line 99: In view of the spelling chosen throughout the manuscript, "parametrisations" is missing an "e".
- Line 123: "(Wilson et al., 2008)" should not be in parentheses.
- Line 128f: These citations also have the wrong format.
- Line 133: I think the "f" in "McFarlane" is supposed to be upper case.
- Equation 1: The bracket is meaningless, unless the square at the end is outside of the bracket (as is the case in Schumann (1996)).
- Line 148: I think the "is" is not necessary.
- Line 150ff and also throughout the manuscript: The units should not be in italics. I would also suggest to stay consistent and use either "⁻¹" or "/".
- Equation 3: I do not think that the bracket in the numerator improves the readability.
- Line 160: "supersaturation" -> "saturation"
- Equation 4: I suppose " Δ_t " represents the time span during which the aircraft crosses the grid box (which is not explained in the paragraph below). In that case I suggest to not put "t" in subscript.
- Equation 5: "M" should be in the same font as in equation 4.
- Line 170: "ICIWC" should be in italics.
- Line 175: "condensation" -> "deposition"
- "large-scale ice and mass" -> "large-scale ice mass and cloud fraction"
- Line 181ff: Sticking with one of the terms "single-moment" or "one-moment" would probably make it easier for the reader to follow.
- Line 188: "as" is redundant.
- Line 194ff: If this is C from equation 4, I suggest inserting a "C" after "cross-sectional area".
- Line 200: "simulation uses" -> "simulations use"
- Line 228: "are shifted upwards" -> "extend higher up in the mid-latitudes"
- Figure 1 and also later figures: The abscissa for CAM includes the poles, while the one for the UM does not. Maybe this can be aligned.
- Line 258: Suggestion: "The contrail fraction and ice mass mixing ratio of young contrails, i.e. contrails in the first model time step of their life cycle, are diagnosed ..."
- Line 261 and later: If I understand this correctly, "contrail fraction" was the fraction of a grid box filled with contrails up to this point, whereas from now on it is the fraction of a model column "covered" by contrails. If this is correct, I would suggest to introduce a new quantity "contrail coverage" or "contrail cover fraction" at this point to distinguish the two. Furthermore, I would suggest to switch the order of "fraction" and "ice water path", whenever used after "young contrail", to make clear that the young contrail ice water path is meant and not the overall ice water path.
- Line 268: The formatting of the geolocation makes it hard to read. "35° N-60° N" -> "35°N – 60°N"
- Line 281f: Chen et al. (2012) is cited twice here in the same sentence.
- Line 290: "ice supersaturation" -> "ice supersaturation frequency"
- Line 302: "vertical level height" -> "vertical layer thickness"
- Line 304: Suggestion: Add "the" before "CAM5 value"

- Line 306f: “persistent contrails within one model timestep” -> “persistent contrails created within the latest model timestep”
- Line 309: The reference to “Bock and Burkhardt (2016)” has the wrong format.
- Line 313f: This does not really make clear, how many control runs there were per model. Please rewrite, e.g. “between the 20 perturbed ensemble runs (with contrails) and the control run (without contrails) for each model.”
- Line 315: “student-T test” -> “Student’s t-test”
- Line 319ff: I suppose all percentages given in this paragraph are relative changes, although this is only stated once. Maybe this can be clarified also for the other percentages by adding some “relative”s, as these could also be absolute changes in cloud fraction.
- Line 327: “contrails” -> “contrail”
- Figures 4 & 5: Maybe the first two sentences of the caption can be joined with an “and”, and mentioning the AEDT air traffic inventory once should then be enough. Furthermore, I missed an explanation of the contour lines in the plots. In figure 4a, “change” is the only word in the plot title that is not written with a capital.
- Line 340: “overall cloud water content” -> “cloud ice content”
- Line 344: “evaporation” -> “sublimation”
- Line 346: “evaporate” -> “sublimate”
- Line 348: The second “larger increases” seems a bit redundant.
- Line 364: The references should be in one pair of parentheses.
- Figure 6: “kg/m2” -> “kg m⁻²”. I would also suggest to put “(a)” and “(b)” in front of the respective panel description and not at the end. I would also be good to mention the strongly changed colour scale compared to figure 5.
- Figures 7 & 8: “forcing” in the plot title of panel b should be written with a capital. In the caption of figure 8 “(B)” should not be a capital.
- Line 418f: “young contrail fraction and ice water path” -> “young contrail ice water path and fraction” or “young contrail fraction and young contrail ice water path”, as this statement is not true for the overall ice water path.
- Line 440: “models” -> “models” or “model”
- Line 445: The format of the citation is incorrect.

Reference:

- Bickel, M. (2023). *Climate impact of contrail cirrus* (Doctoral dissertation, lmu).